

Carbon Conversion Program Overview and Wider Thoughts



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National Energy Technology Laboratory (NETL)



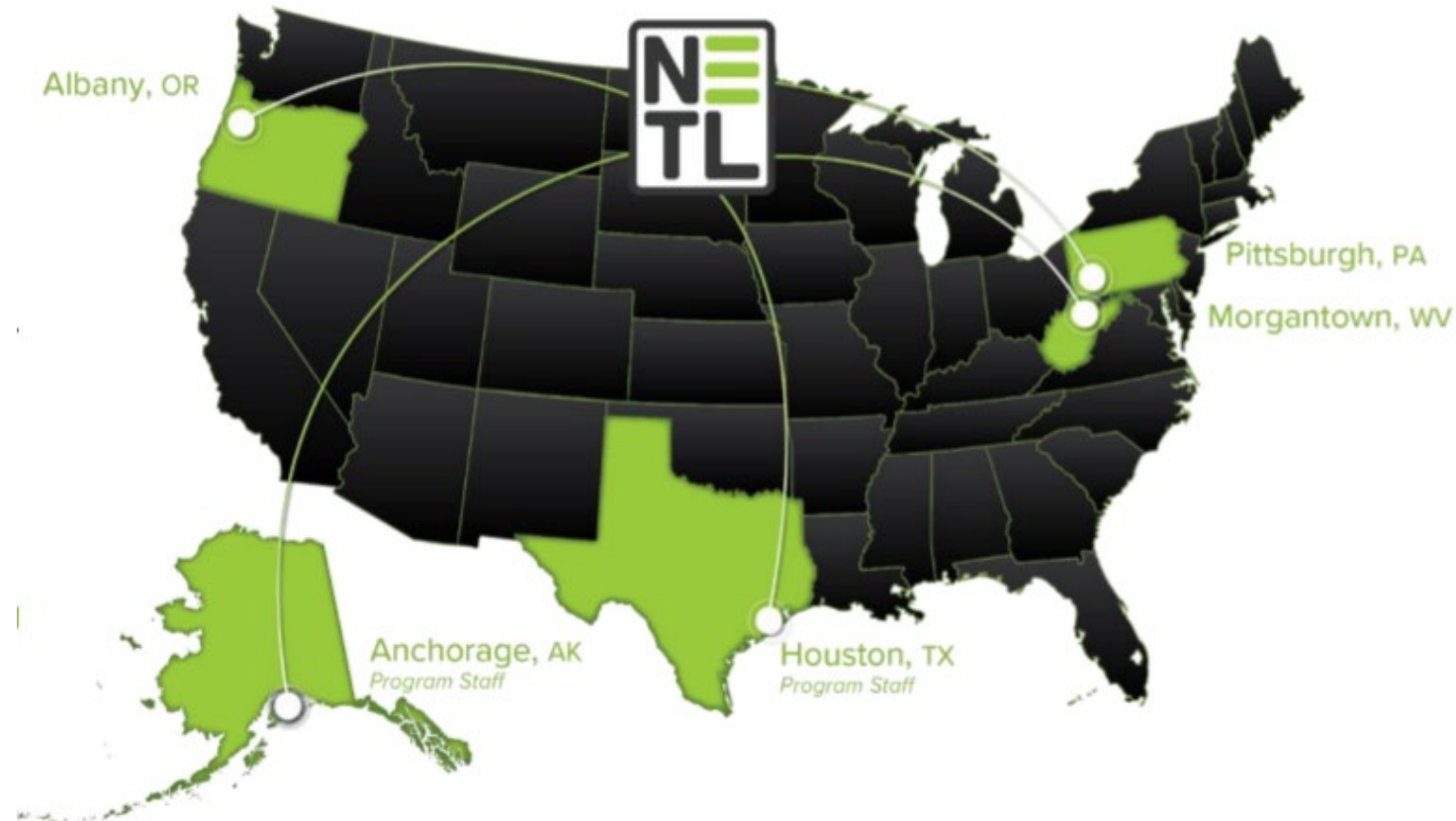
One of 17 U.S. Department of Energy (DOE) national laboratories; producing technological solutions to America's energy challenges.

Mission

- Ensuring affordable, abundant and reliable energy that drives a robust economy and national security, while
- Developing technologies to manage carbon across the full life cycle, and
- Enabling environmental sustainability for all Americans.

Vision

- To be the nation's premier energy technology laboratory, delivering integrated solutions to enable transformation to a sustainable energy future.



Mission

- Advance carbon management through carbon conversion

Goals

- Support R&D that can convert CO₂ into products
 - Conversion must be environmentally and economically attractive
- Support scaling (demonstration) of technology where appropriate

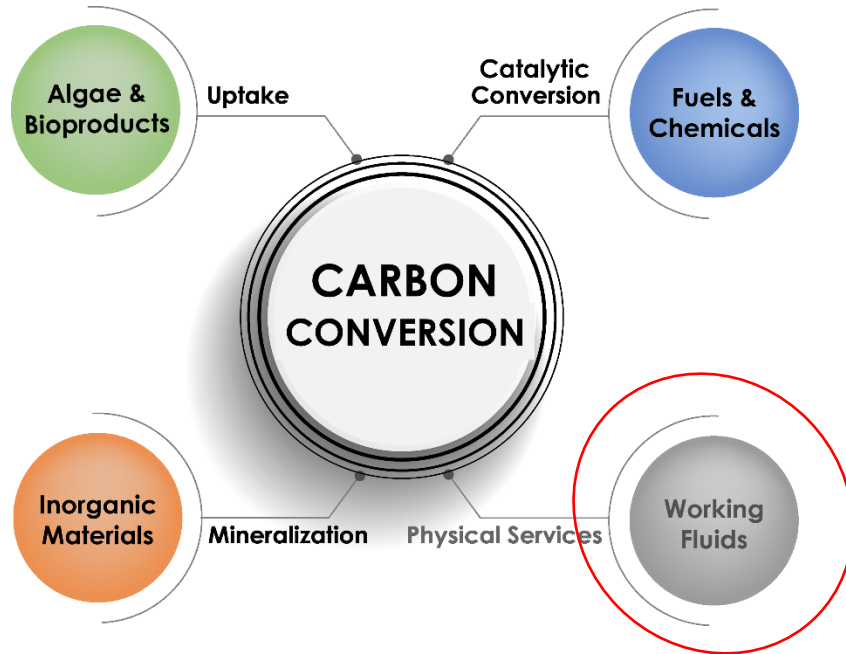
Drivers

- United States 2020 CO₂ emissions $\approx$ 4.7 gigatonnes
 - Total global CO₂ emissions in 2021 $\approx$ 36.3 gigatonnes

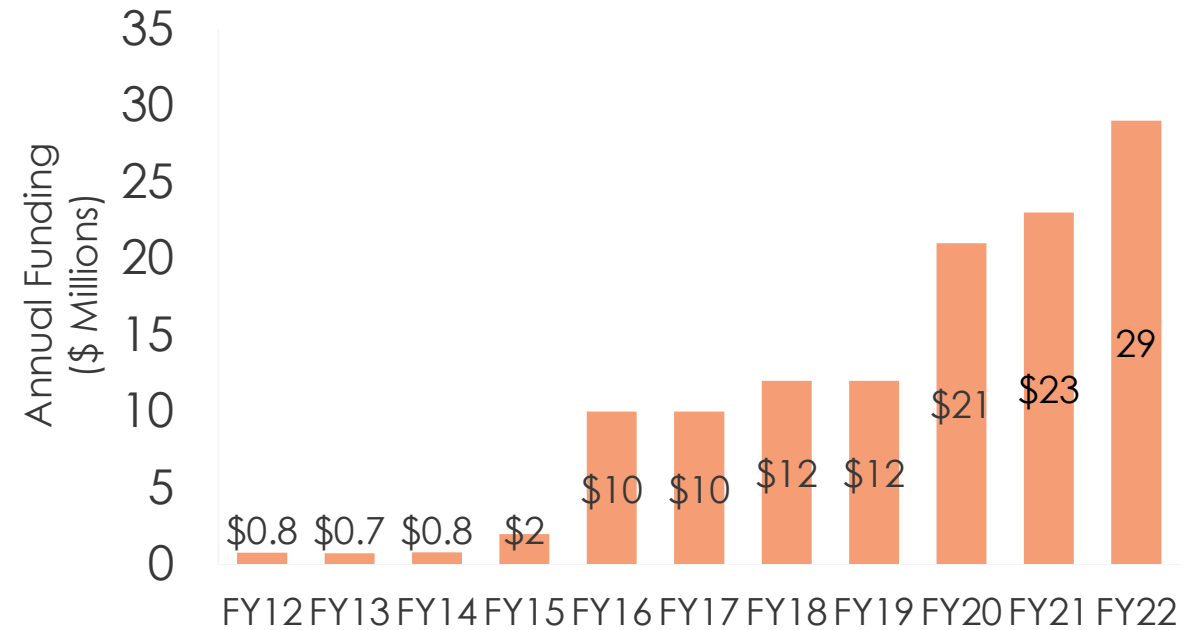
Challenges

- Scale of CO₂ emissions relative to CO₂ consumption
- Qualifying economic viability and environmental impact requires significant resources
- Electricity prices rarely negative/free
- “Prototypes are easy, production is hard”

Carbon Conversion Program R&D Areas



Focus of other programs



Carbon Conversion Program Within NETL



<https://netl.doe.gov/carbon-management/carbon-utilization>

NETL CO2U LCA GUIDANCE TOOLKIT

CO2U LCA GUIDANCE DOCUMENT FOR THE U.S. DOE OFFICE OF FECM, VERSION 2.0

Analysis requirements and instructions for using the supporting data and tools

NETL CO2U LCA DOCUMENTATION SPREADSHEET

Excel file that can be used to document data when not using openLCA

TRAINING RESOURCES

Provided to funding recipients to aid in modeling an LCA

NETL CO2U OPENLCA LCI DATABASE VERSION 2.1

openLCA database that includes NETL unit process data and an example CO2U LCA

LCA
Life Cycle Analysis

45Q ADDENDUM AND TOOLS

Information pertaining to the use of this toolkit in performing life cycle analyses in support of the 26 CFR § 1.45Q tax credit, including an addendum to the Guidance Document.

OPENLCA CONTRIBUTION TOOL

Excel template that translates openLCA results into required charts

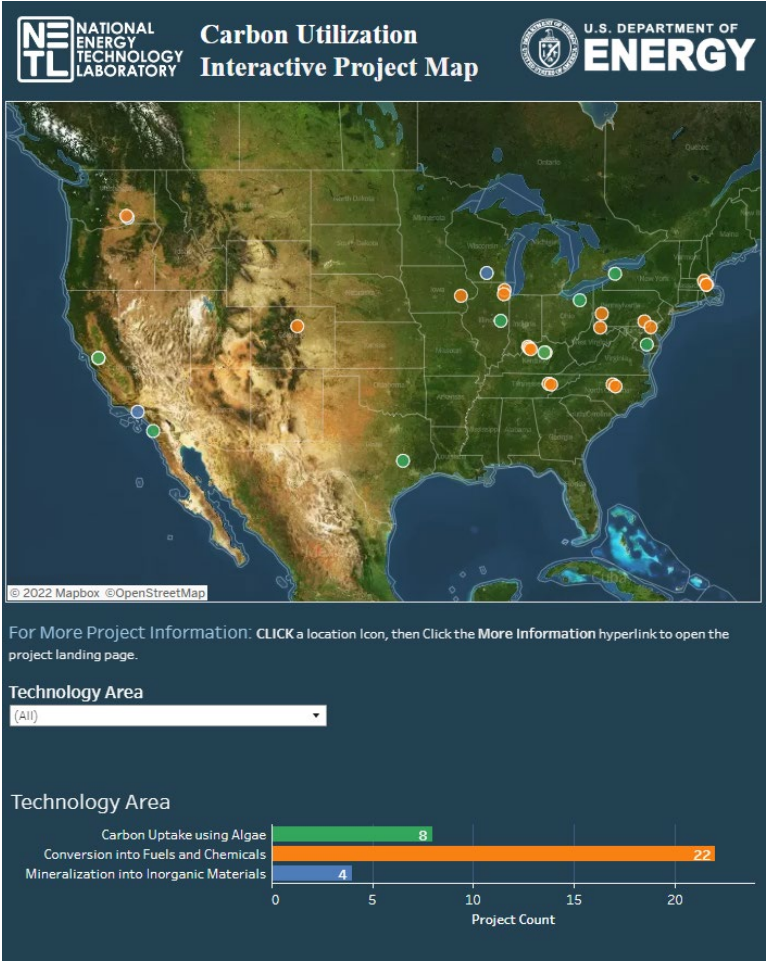
NETL CO2U LCA REPORT TEMPLATE

Word report template for summarizing data and results

NETL ADDITIONAL DOWNLOADS

[Download Full Toolkit](#)

[Patches, Archives, and Version History](#)



R&D through Research and Innovation Center

- Majority focus on conversion into chemicals
- Activity in catalyst design, microwave reformation, reactive capture, and more

Life cycle Analysis through Energy Systems Analysis Team

- Vital to determining economic viability and environmental impact
- Active in Global CO₂ initiative
- Challenges
 - Working to harmonize LCA methodology with other groups
 - Requires collaboration across multiple offices, departments, and external entities

Techno-economic analysis through Energy Process Analysis Team

- All successful technologies must add value
- Sensitivity analysis dependent upon many unknowns
- Not as straightforward to qualify as technical viability

Extramural research outside of NETL

Various funding mechanisms employed

- Field Work Proposals with other national laboratories
- Funding Opportunity Announcements
 - Majority of funding is competitively awarded
- Grant Programs
 - SBIR and STTR for small businesses and institutions of higher education
- Other mechanisms including TCF, ACT, EPSCoR

Robust project portfolio

- Thirty-five active projects within the portfolio and growing quickly
 - Mineralization, catalytic pathway, and biological uptake

Demonstration grant program is not exclusive to FECM/NETL efforts

A range of products are possible

- Animal feeds
- Nutraceuticals
- Dyes/colorants
- Polymers
- Soil amendments
- Fuels
 - Specific to the mission of DOE EERE's BETO (BioEnergy Technologies Office)

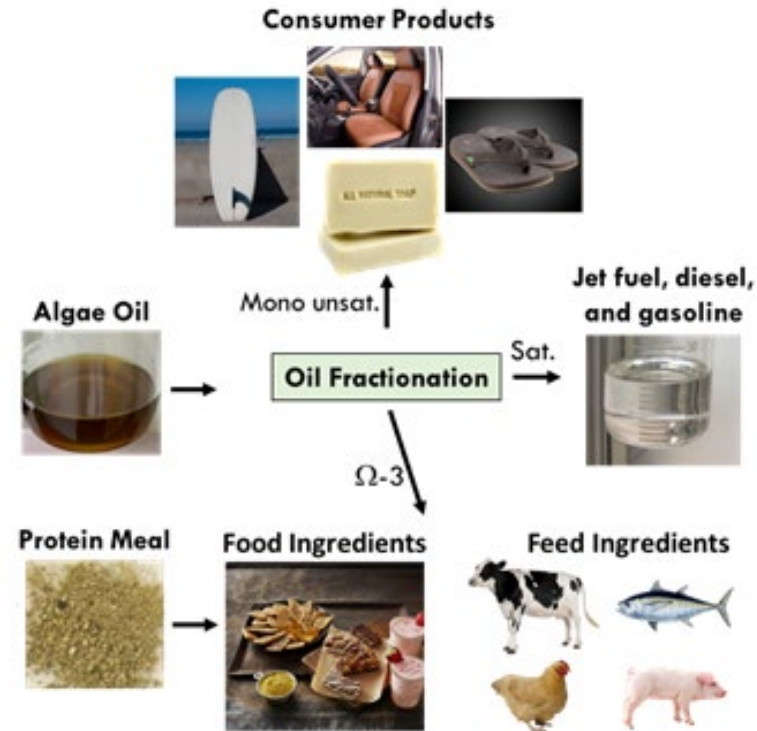
Advantages and challenges

- Uses well understood processes (10,000+ years of human agricultural experience)
- Mostly enabled with catalog engineering (uses COTS equipment)
- Biological processes well suited to creating many complex carbon molecules
- Large areas required to achieve gigatonne scale
 - Kinetically slower than higher temp/pressure processes

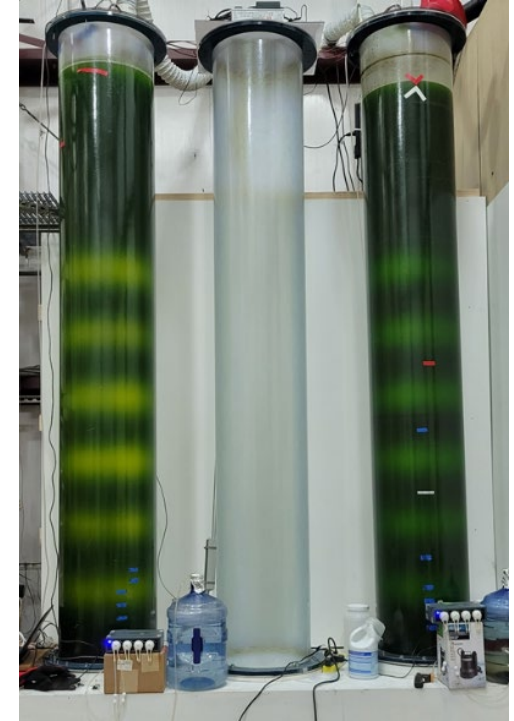
Carbon Conversion via Biological Uptake



Pictures courtesy of
University of Illinois
Urbana-Champaign



Picture courtesy of
Global Algae Innovations



Picture courtesy of
University of Maryland Center
for Environmental Science

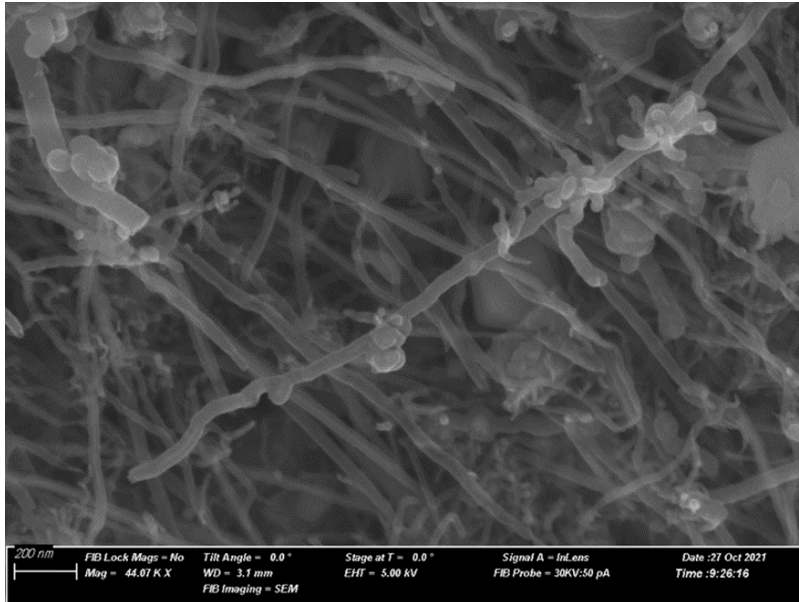
A wide range of products are possible

- Fuels
- Polymers
- Solid carbons
- Alcohols
- C2-C4 products (ethane, propane, butane, etc...)
- Methanol and Methane

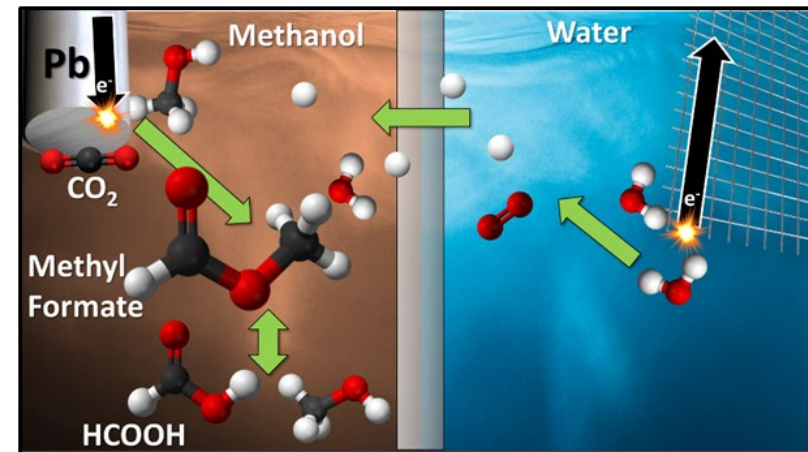
Advantages and challenges

- Pathways to gigatonne scale exist
- Almost any molecule can be synthesized
 - Including those currently derived from fossil fuels
- Value of products must outweigh cost of energy inputs
- Breakthroughs may require significant funding (e.g. electrochemistry and catalysts)

Carbon Conversion via Catalytic Pathway



Picture courtesy of SkyNano



Picture courtesy of University of Louisville

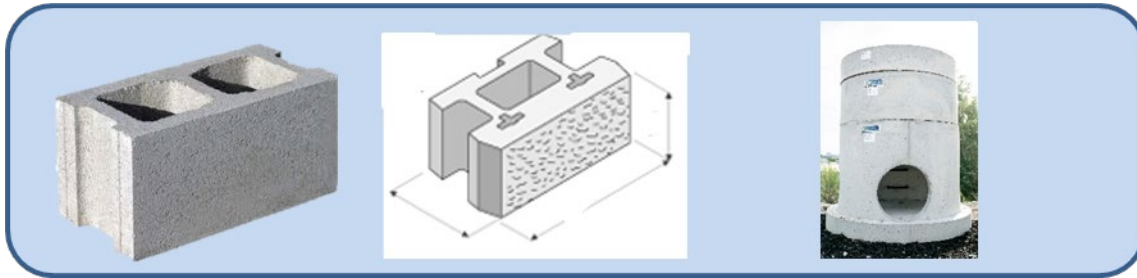
A limited range of products are possible

- Cured concrete blocks (CMU)
- Synthetic aggregates
- Suboxides
- Other building materials

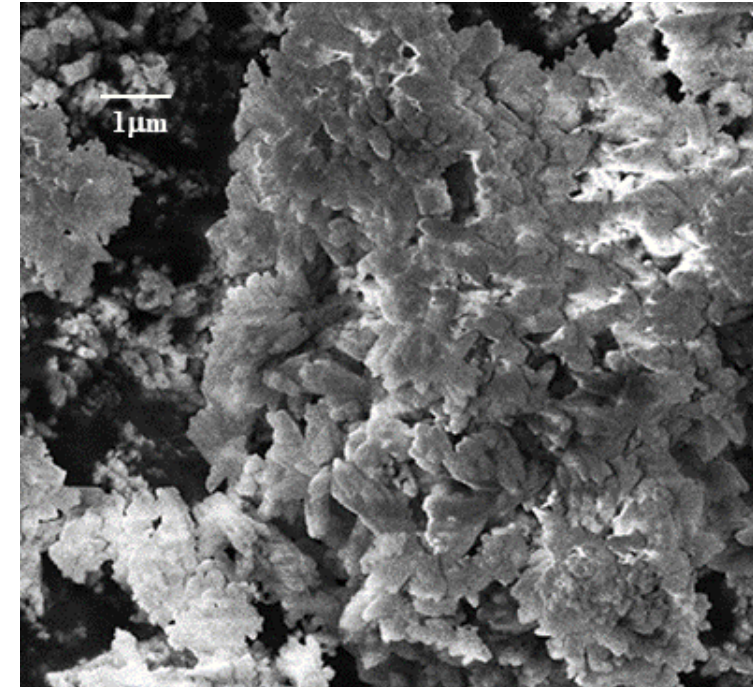
Advantages and challenges

- Can be energetically downhill
- Can apply at gigatonne scale
- Mostly enabled with catalog engineering (uses COTS equipment)
- Can address other waste streams (e.g. produced water or mine tailings)
- Products often have a low specific value (i.e. \$/tonne requires large scale)

Carbon Conversion via Mineralization



Pictures courtesy of UCLA



Picture courtesy of University of Wisconsin Madison

Necessity of TEA/LCA for an Uncertain Future

Tomorrow will look a lot like today

- Mix of fossil, renewable, and nuclear resources
 - Abundant waste heat integration opportunities
- Industrial electricity prices of \$60 - \$80 / MWh

Inexpensive and abundant hydrogen

- \$1/kg Hydrogen
 - Thermochemical conversion of CO₂ into chemicals and plastics
 - Industry widely decarbonized (e.g. steel, cement, fertilizer)

Techno-cornucopian worldview

- Inexpensive electricity at \$20 - \$30 / MWh
- Widescale electrification
- Favorable for electrochemical approaches

Other unknowns

- Carbon prices/credits, DAC costs, energy breakthroughs, etc...

Expanding the program

- Funding for program is increasing quickly
- Interest is increasing even more quickly than funding

Collaboration with multiple stakeholders

- Necessary due to the scale and breadth of the challenge
- It's not just FECM; lots of other DOE Offices, USG Departments, and NGOs involved

Program supports capabilities to test technologies at scale

- National Carbon Capture Center (NCCC)
- First USG funding source to support UCLA CarbonBuilt technology
 - One of two winners of prestigious NRG COSIA XPRIZE

Supporting R&D across multiple pathways

- Biological, thermos/electro chemical, mineralization, and reactive capture

TEA and LCA are vital for an effective program

- “It’s tough to make predictions, especially about the future”

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<https://netl.doe.gov/coal/carbon-utilization>